FINAL TECHNICAL REPORT

NASA IUE PROGRAM GRANT NAG5-1283

Comparison of Nearby and Very-High-Redshift Radio Galaxies

Principal Investigator: William C. Keel, University of Alabama

Prepared November 1991

This research was designed to provide a baseline set of observations of nearby radio galaxies against which comparison could be made with high-redshift objects seen at large look-back times from ground-based or spaceborne instruments. We obtained or reprocessed IUE observations for eight nearby radio galaxies, and measured both continuum shapes and Lyman α emission properties. The systematic properties of the nearby objects, and a preliminary comparison with galaxies at redshifts $z = 2 - 3$, show that:

1. Low-redshift radio galaxies show Lyman α emission at moderate power. There is evidence, in comparison with objects at higher redshifts observed from the ground, that the emission-line and radio-continuum luminosities are correlated. This marks the first use of a single emission feature to trace this correlation over such a large redshift and luminosity range.

2. The nearby objects appear more likely to show a UV upturn than non-radio ellipticals of similar luminosity. This may indicate unusual star-forming histories for the radio galaxies, and connect the AGN and starburst phenomena for radio galaxies.

3. The Lyman-to-Balmer emission-line ratios indicate depletion of Lyman α in nearby systems, possibly due to destruction by grains during resonant scattering within the narrow-line region. Thus, such line ratios in high-redshift galaxies may be differently modified by radiative transfer, since very young galaxies might have a less extensive grain component.

These results have been used as template spectra in formulating a followup proposal for use of the *Hubble Space Telescope*. A full description of the analysis is in press for the Dec. 10, 1991 issue of the *Astrophysical Journal*; a copy of this manuscript was provided with the previous semiannual report.

FINAL REPORT – NASA-IUE Grant NAG 5-1283 – March - Sept. 1990

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William C. Keel (PI)
University of Alabama
Tuscaloosa, AL 35487

During this period, we obtained new IUE spectra for two nearby radio galaxies and reprocessed archival data for four more. These observations have been combined with new ground-based data to allow a comparison between these relatively well-understood objects and their most likely counterparts now being found at high redshifts. Such a comparison requires a systematic IUE data base, because ground-based observations of the most distant objects sample only the emitted-frame ultraviolet spectrum.

The enclosed paper (submitted to the *Astrophysical Journal*) describes our new IUE data base as well as the comparison to the optical spectra of recently observed very high redshift radio galaxies. In order to study the effects of spectral evolution in high redshift radio galaxies, we must compare these objects to the UV spectra of their most likely present-day counterparts. These should be low redshift radio galaxies of similar radio power (accounting for the luminosity evolution expected for the radio source population, e.g. Windhorst, Mathis, and Neuschaefer 1990).

We argue that the most likely low redshift counterparts of these very high redshift ($z>>1$) radio galaxies are LINER's. We therefore obtained and reprocessed short wavelength IUE spectra for half a dozen nearby elliptical galaxies ($V<15$ mag) that have weak LINERs in their centers. Our comparison of the nearby and high redshift galaxies show the following:

1) Ly-α emission is common among local radio galaxies, at levels much weaker than those observed at high redshift. Extrapolation to galaxies such as Cygnus A suggests that this decrease has been about a factor 10 for the most powerful radio sources.

2) There is no evidence for substantial differences in UV line ratios, but the lines are so weak that this conclusion largely reflects upper limits.

3) The ratio of Ly-α to Hα in nearby objects falls well below the prediction for case B recombination, perhaps due to destruction of Ly-α photons by grains during resonant scattering. If the dust content of these galaxies has increased over cosmic time, high redshift galaxies should have relatively stronger Ly-α emission by as much as a factor of 4. This is a significant part of the systematic difference observed, and indirectly traces the evolution of the stellar populations.

4) Many low-redshift systems show a characteristic upturn in the continuum (shortward of 1500 Å) which is lacking in recently studied high redshift galaxies. We extend previous comparisons and suggest that this general behavior is a direct consequence of the spectral evolution of these galaxies.

The presence of this feature in nearby galaxies, and its absence in high redshift young galaxies, appears to be a general rule. We believe that this is a direct result of their spectral evolution. The reasons for stronger emission lines in the high redshift galaxies remain unclear. The spectra do not in themselves suggest different modes of ionization, though arguments from ionization parameter distributions in nearby and high redshift galaxies indicate that a minimum ionization level, due to hot evolved stars, should have grown with time to its present value, and thus that this mechanism would not have applied early on. Rather, ionization more directly related to the central radio source seems to have been dominant in the epochs sampled at redshifts 1–3. Higher-quality UV spectra, and inclusion of objects at intermediate redshifts, will be needed to distinguish among these possibilities.

Encl: Preprint IUE paper submitted by Keel and Windhorst to the *Astrophysical Journal.*

Keel and Windhorst